Unanticipated Airway Emergencies: Resuscitation in the Delivery Room and Emergency Department

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Section 1: Resuscitation in the Delivery Room

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Preparation for a Routine Delivery

In general, in order to adequately resuscitate and stabilize a newborn with anticipated difficulties, the delivery room should be prepared adequately. To do this effectively the most important basic questions that need to be answered are

1. What is the gestational age?
2. Is the fluid clear?
3. How many babies are expected?
4. Are there any additional risk factors?

Importance of Gestational age

Preterm newborns at high risk of primary apnea are more likely to need higher levels of resuscitation and establishing an airway is also more challenging. If time allows ensuring an advanced airway skills person such as a neonatologist, pediatrician, anesthesiologist be present at the delivery is helpful. In addition for resuscitation of the preterm neonate, additional equipment may be needed to ensure thermoregulation and establishing vascular access in the delivery room. Moreover and if possible, a preterm infant with suspected or confirmed airway anomalies with an anticipated difficult or critical airway should preferably have a pediatric ENT in attendance.

Significance of Meconium at the Delivery

Meconium-stained amniotic fluid may be a sign of fetal distress, newborns born through meconium-stained amniotic fluid are at risk for aspirating it after birth. The current NRP guidelines recommend that if a baby is delivered through meconium-stained amniotic fluid, a quick assessment of the baby's well being of vigor should be made. Vigor implies a baby who is not exhibiting signs of distress namely a HR >100, good tone and strong breathing or crying. If the baby is not vigorous i.e. missing any one of the above then it is recommended to intubate the baby for deep tracheal suctioning. Tracheal suctioning is done to prevent aspiration of meconium into the lungs. If meconium is recovered the first time the provider may repeat tracheal suctioning provided the baby remains stable. If no meconium is recovered or the baby becomes unstable at any given point, one must immediately abandon intubation attempts and start resuscitation from the very top of the NRP algorithm.

Multiple Births

Multiple Gestation delivery babies may need more resuscitation and always need more equipment and personnel. Often, there can be comorbidities that exist such as discordancy, twin-to-twin transfusion syndrome, and entrapment of one twin due to malposition.

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Other Risk Factors

Any significant findings in the history that could affect resuscitation causing airway difficulties such as polyhydramnios, suspected birth defects of the neck, trachea, esophagus, chromosome abnormality with severe micrognathia, and other craniofacial anomalies such as hemifacial microsomia can cause a serious situation for an unprepared team.

Evaluation of the Newborn at Delivery

After the delivery of the baby, answering three questions will determine the need for the initial steps at the radiant heat warmer
Is the newborn term?
Is the newborn breathing or crying?
Does the newborn have good muscle tone?

If the answer is NO to any question start NRP.

Currently the 6th *Edition of the Neonatal Resuscitation Program is considered the standard of care in neonatal resuscitation. We have described steps of neonatal resuscitation in detail in the following sections based on the NRP guidelines* (Please see 6th Ed. NRP manual for details).

Initial Steps

The NRP algorithm recommends starting with warming and drying any newborn in need for resuscitation. This will stimulate the baby to breathe, and a majority of newborns will just require this in order to start breathing. If the baby shows signs of airway obstruction oral and nasal suctioning can aid with stabilizing the airway.

At many large high volume obstetrical hospitals with academic connections, airway algorithms are available for staff review and preparation:

Administering Positive Pressure Ventilation

Positive Pressure ventilation may need to be administered according to the NRP algorithm after the initial steps or warming, drying, and stimulating the baby if the baby is apneic or gasping or has a heart rate of <100 beats per minute, persistent central cyanosis or desaturations despite increasing the FiO_2 to 100 %.

The two systems used for this purpose are a flow-inflating bag, self-inflating bag, or a T-piece resuscitator. When PPV is administered ensure there is a manometer in line to avoid barotraumas. The PPV is administered at a rate of about 30 breaths per minute.

Ensure adequate chest rise and air entry to assess effectiveness of PPV. The most consistent response to effective PPV will be an improvement in the HR and saturations.

Priority in Neonatal Resuscitation always remains establishing effective ventilation.

If the baby does not respond to the initial 30 s of PPV NRP recommends all providers to go through a series of ventilation corrective steps to ensure that PPV is in fact effective. The pneumonic is
M: Adjust Mask in the face
R: Reposition the head to open airway
S: Suction mouth and then nose
O: Open mouth and lift jaw forward
P: Gradually increase Pressure every few breaths until visible chest rise is noted

If this does not lead to improvement in heart rate, an Artificial Airway (ETT or LMA) should be considered.

Intubation and Use of a Laryngeal Mask Airway or LMA

An LMA may be indicated as an alternative to intubation when facial or upper airway malformations render bag-mask ventilations ineffective or PPV not effective and intubation is not possible.

Pulse Oximetry and Evaluation of Color

Pulse oximetry is an important tool to gauge the saturations of a baby in distress. It should be used if:

1. Resuscitation is anticipated
2. PPV is required for more than a few breaths
3. Central cyanosis is persistent
4. To confirm your perception of central cyanosis
5. Whenever supplemental oxygen is administered

In general, term infants may be resuscitated with 21 % O_2. Preterm infants may begin with a somewhat higher oxygen concentration. When using pulse oximetry pulse Ox probe on right hand or wrist as it measures the pre-ductal saturation.

Of note one must place on patient before connecting to Pox machine to achieve the fastest readings. Supplemental oxygen concentration should be adjusted gradually to achieve pre-ductal Saturations summarized in the NRP diagram below (Both Term & Preterm).

Chest Compressions

Chest compressions may need to be initiated per the NRP algorithm if the HR <60 bpm despite effective ventilation. One must coordinate chest compressions with ventilations for at least 45–60 s before stopping briefly to assess heart rate.

Compress 1/3 diameter of chest with 90 compressions to 30 ventilations/min (120 events). A good way to coordinate the compressions with ventilations is to call out One & two & three & breathe & One & two & three & breathe &….

Other things to remember are to increase FiO_2 to 100 % once you begin compressions. Pox may not work while newborn is receiving chest compressions.

Intubation is strongly recommended when compressions begin.

Umblical Venous Catheter UVC Placement and Epinephrine

Consider placement of UVC once compressions are initiated or if extended resuscitation is anticipated. Continue chest compressions by moving around to head of bed to allow room for MD to place UVC. Epinephrine is indicated when heart rate remains <60 despite 30 s of effective ventilations and at least another 45–60 s of coordinated compressions and ventilations.

Epinephrine

The ETT route has an unreliable absorption, which renders it less effective, but if it may be readily available so may be given while attempting to establish a UVC.

The UVC route is the preferred method for administering epinephrine; however, it requires a skilled person to place immediately. The IV epinephrine may be given as soon as the line is placed even after just giving via ETT. Doses of epinephrine are based upon the different concentrations used for different routes of administrations.

Post-resuscitation Care

There are two levels of post-resuscitation care:

Routine Care, which is for vigorous term infants with no risk factors or babies who required but responded to initial steps. These babies now can stay with their mothers and skin-to-skin contact recommended.

Extended Care is for babies with depressed breathing or activity such as those requiring supplemental oxygen &/or ongoing nursing care and those with high-risk factors requiring frequent evaluation may need to be evaluated in an ICU setting. These babies may possibly then transfer to routine care after a period of stability.

Role of T-Piece Resuscitator (TPR)

Effective positive pressure ventilation can be vital to neonatal resuscitation, in addition it is also important for uniform and effective surfactant distribution. A T-piece resuscitator TPR or the traditional flow bag valve mask apparatus can deliver this positive pressure. The TPR provides pressure-controlled, flow-delivered positive pressure ventilation. The positive end expiratory pressure (PEEP) valve can be rotated to modify the PEEP provided, and occlusion of the valve by the operator delivers peak inspiratory pressure (PIP). Its main purported advantages are the delivery of consistent pressures, the ability to adjust inspiratory time, and the control of PIP and PEEP. There is a wide variability in the use of T-piece resuscitator in neonatal resuscitations.

TPR users should also be aware of certain limitations of the device. Resuscitation is a dynamic process where the resuscitator needs to adapt to the response or non-response of the newborn. TPR users are not as good at detecting changes in compliance as users of the Self or Flow-inflating bags. TPR users also need more time to change the inflating pressures during resuscitation, compared to users of the SIB or FIB. Mask leak is greater with the TPR than with other devices.

TPRs are also the most technically difficult of the three devices to prepare for use. Operators who do not frequently use the device, and are not receiving regular training in its setup, forget how to prepare the device for use. Instructors should be aware that increases in gas flow before, or during resuscitation could result in significant increases in pressures unless the operator adjusts the dials accordingly.

Until evidence of clinical benefit is available, we recommend that healthcare providers are appropriately and regularly trained in the use of whatever device being used in their clinical practice, and are aware of the particular limitations of that device.

Identification and Evaluation of High-Risk Neonate with Difficult/Critical Airway

Neonatal airway obstruction, a frequent cause of respiratory distress, is a common indication for NICU admission. Ventilation is the cornerstone of neonatal resuscitation and when airway obstruction presents in the delivery room, it poses a unique challenge to transition the neonate. Presence of airway obstruction in the delivery room may be unexpected and may escalate to life-threatening situations or present at facilities that do not routinely cater to high-risk population.

Prenatal history and findings may give the neonatal provider valuable clues towards making the diagnoses. However, the same may not always be available or known prenatally. Thus, the delivery room may serve as the first opportunity or site for the presentation and detection of neonatal obstruction. Ventilation is the cornerstone of neonatal resuscitation and when airway obstruction presents in the delivery room, it poses a unique challenge to transition the neonate. Thus it is of utmost importance for the neonatal provide to review all available prenatal information when available that maybe pertinent for the neonate's delivery room needs.

Table 1 Epinephrine administration guidelines for resuscitation

• Concentration 1:10,000 (0.1 mg/mL)
• ETT dose is 0.5–1 mL/kg
• UVC/IV dose is 0.1–0.3 mL/kg
• Follow with a 0.5–1 mL flush NS
• Re-check heart rate after 1 min of compressions and ventilations
• Repeat dose every 3–5 min

Table 2 Special considerations for preterm neonates

1. Increase temperature of the delivery room to approx. 25–26°C (77–79°F)
2. Polyethylene plastic wrap
3. Place portable warming pad under the layers of
4. Towels at the radiant heat warmer
5. Use blended O_2
6. Consider CPAP for good heart rate but an increased work of breathing
7. May need to administer surfactant for preterm infants intubated for respiratory distress syndrome or RDS

Table 3 Prenatal ultrasound finding associated with neonatal airway obstruction. Congenital high airway obstruction, (CHAOS)

Non-immune Hydrops—severe neck edema
Polyhydramnios with tracheal atresia
Severe Micrognathia-craniofacial/genetic syndromes
Large echogenic fetal lungs-upper airway obstruction
Dilated airways with stenosis
Cervical lymphangiomas/teratomas
Neuromuscular condition with arthrogryposis and jaw immobility

Table 4 Common causes of neonatal airway that may present in the delivery room setting

Conditions associated with extrinsic compression of the airway
1. Cervical lymphatic malformation (cystic hygroma)
2. Cervical teratoma
3. Associated with mandibular hypoplasia:
(a) Pierre Robin sequence (Stickler syndrome)
(b) Nager Syndrome
(c) Treacher Collins Syndrome
(d) Bilateral hemifacial microsomia—Goldenhars Syndrome
4. Associated with macroglossia
(a) Down's Syndrome
(b) Beckwith Weidmann Syndrome
(c) Lymphangioma
Conditions associated with intrinsic airway compression
1. Lingual thyroid
2. Vallecular cyst
3. Others, such as Nasal encephalocele, ranula, glioma, dermoids, etc.
Intrinsic airway obstruction
1. Choanal atresia/stenosis
2. Tracheal agenesis/stenosis
3. Laryngeal agenesis/stenosis
4. Congenital high airway obstruction sequence (CHAOS)
5. Vocal cord palsy (primary condition, associated with hydrocephalus)
6. Laryngeal web
7. Tracheomalacia/Laryngomalacia

Prenatal Diagnoses and Fetal surveillance

Ultrasound remains the first and main diagnostic modality for fetal assessment [1]. Anatomic fetal surveillance is usually performed at 18–22 weeks gestation. In high-risk case, fetal MRI has been employed with significant benefit. Fetal MRI does have technical challenges but gives a level of anatomic detail that may have substantial prognostic and therapeutic implications [2, 3]. Table 1 lists the most common prenatal imaging and clinical findings that raise the possibility of neonatal or fetal airway obstruction [4]. Many neonates are now born in centers with "fetal therapy programs" and delivery units within specialized Children's Hospitals. However, many of these neonates must be born in larger maternity hospitals due to maternal reasons: (severe pre-eclampsia; HELLP syndrome; acute bleeding; maternal cardiac disorders). These are the infants that will be delivered in a perinatal center and those with airway issues will be the challenge for the team at resuscitation:

It is important to note that while actual anatomical details such as cervical neck masses give a direct clue towards the likely airway obstruction, other findings maybe more indirect and thus evade an easy association. These indirect clues may arise as a consequence of airway obstruction, such as hydrops or polyhydramnios. They may also be part of a syndrome of which airway obstruction is a feature. A good example of this is coexistence of structural heart anomalies and coloboma in a fetus may alert the provider to the possibility of choanal atresia as part of the CHARGE syndrome (previously thought to be an association). As such existence of major congenital anomalies should raise the index of suspicion for airway anomalies as part of a global pathology. Other syndromes such as Treacher Collins, Goldenhars and Pierre Robin syndromes can also present with significant airway obstruction due to the severe micrognathia. Common diagnoses associated with neonatal airway obstruction that may present in the delivery room are listed in Tables 2, 3 and 4.

However, during intubation, conditions affecting the supra, glottic and subglottic area may only then become obvious and hinder the neonatologist from routine intubation. Conditions such as subglottic stenosis, masses, vocal cord paralysis, or atresia can be uncovered in the delivery room.

Airway Emergencies in the Delivery Room

Specific airway-related diagnoses, such as listed above likely mandate a customized approach to neonatal resuscitation. Another group of conditions that deserves a special mention here, comprise conditions that are not directly associated

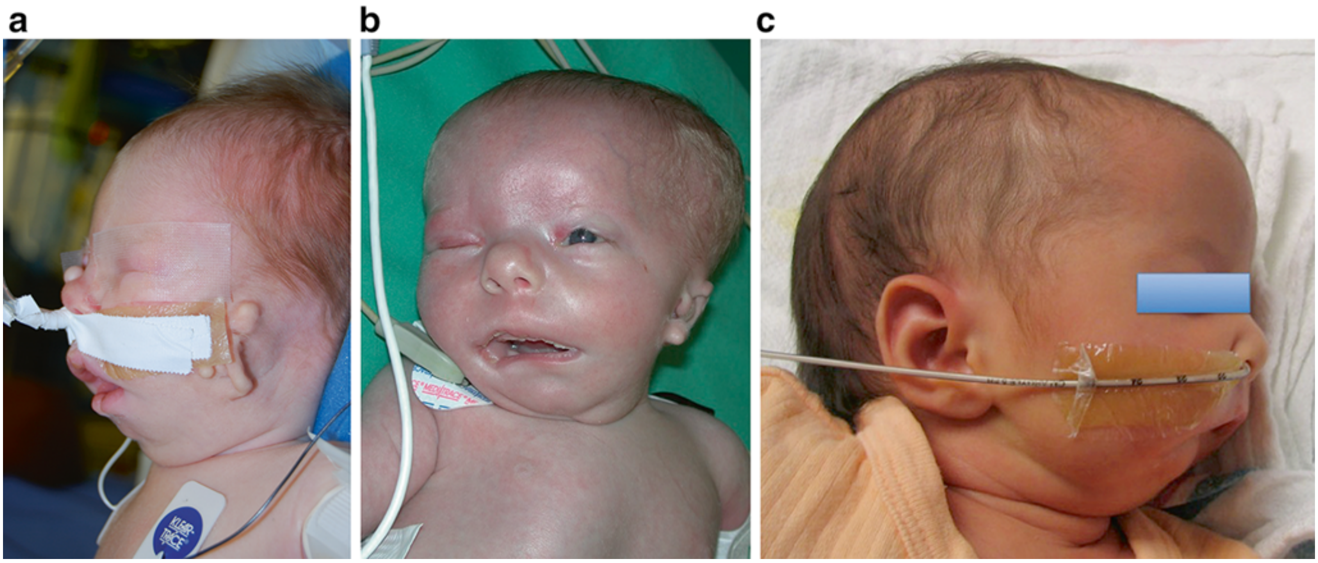

Fig. 1 (**a–c**) Goldenhars Syndrome with severe micrognathia and airway obstruction requiring specialized airway management in immediate birth period

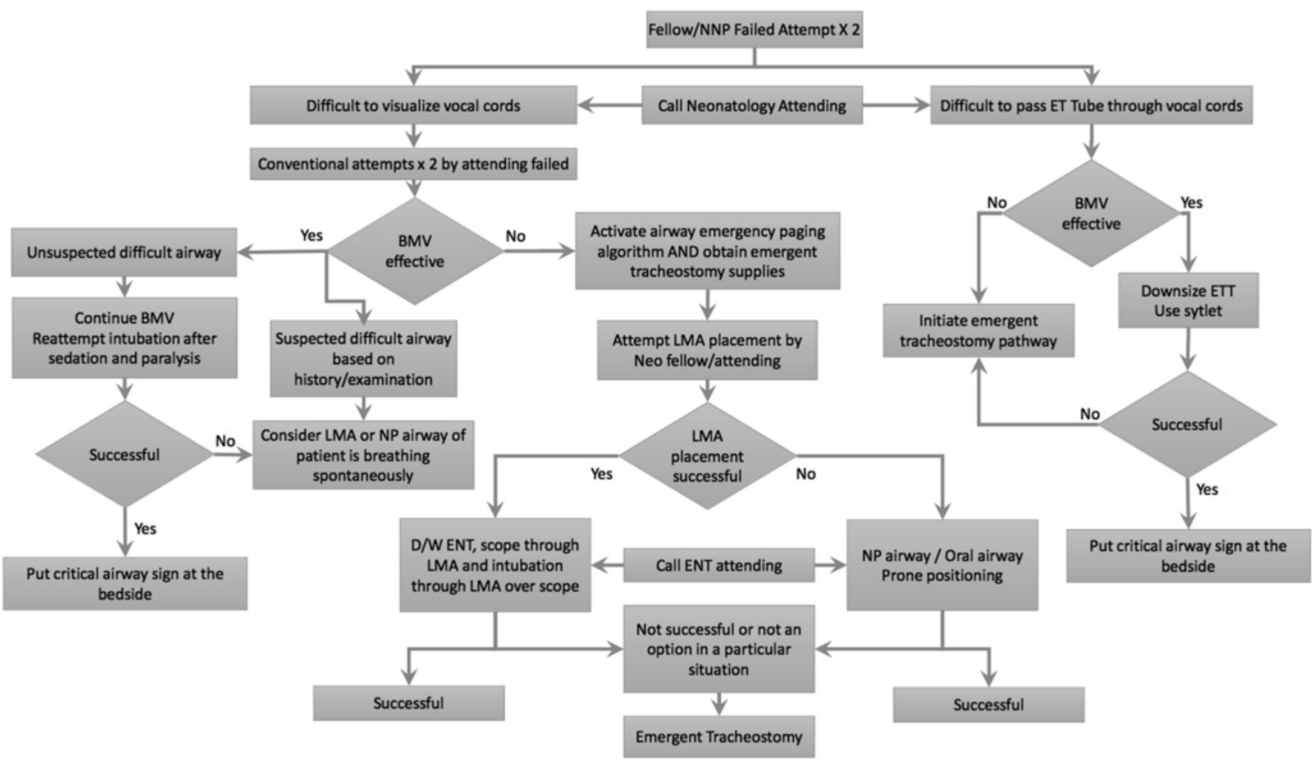

Fig. 2 Delivery room airway emergency algorithm:**Courtesy of Michael Posencheg, MD, medical director of the Hospital of the University of Pennsylvania neonatal unit. **

with a specific airway diagnoses, nevertheless have implications for airway management in the delivery room. These mainly include conditions wherein the role of bag-mask ventilation is limited and prompt orotracheal intubation is recommended for example, esophageal atresia, and congenital diaphragmatic hernia.

Once an airway obstruction has been identified, the fetus needs to be evaluated for other possible coexisting conditions. The airway obstructions maybe an isolated finding or part of a global/syndromic condition. The latter raises serious ethical questions as more neonates with severe birth defects are now being born at Children's Hospitals with immediate access to

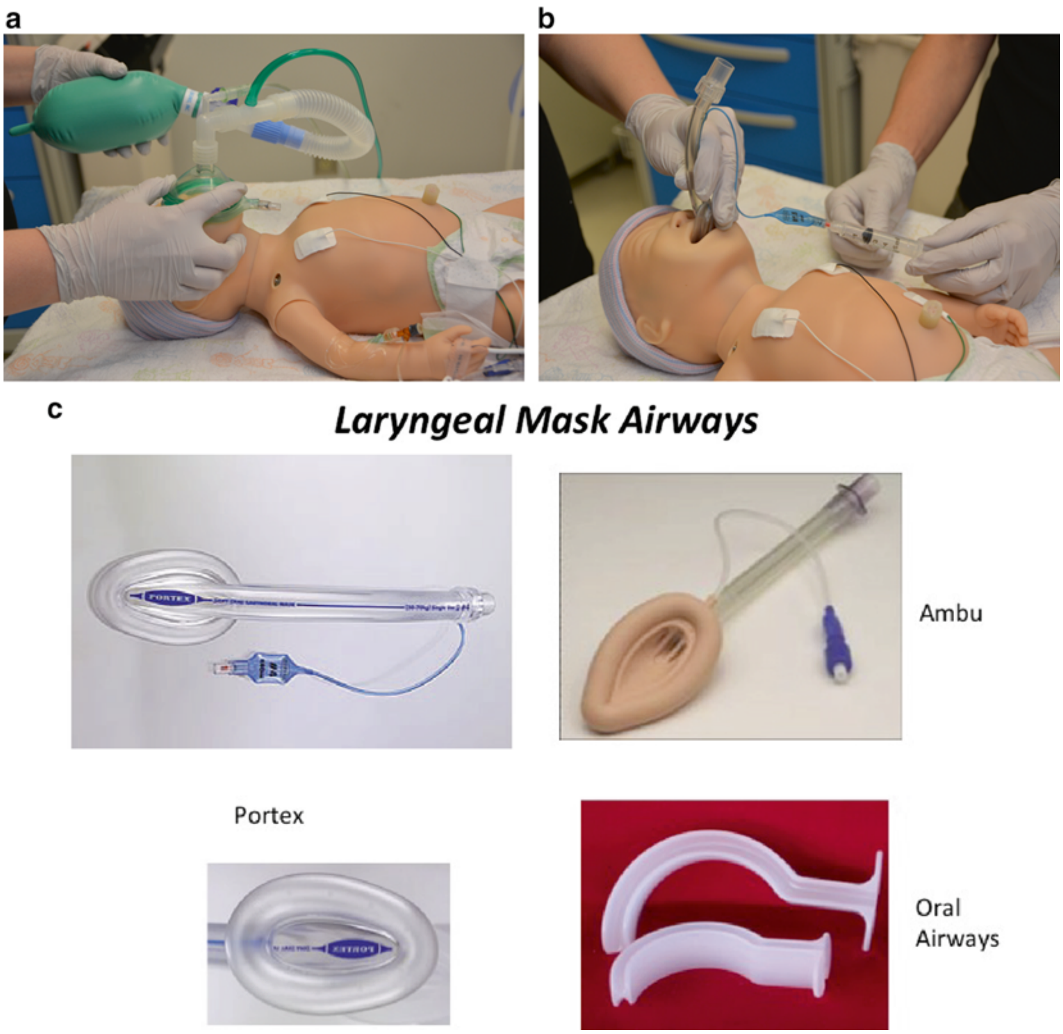

Fig. 3 (**a**) BMV placement in a neonate. (**b**) LMA Placement in a neonate. (**c**) Different LMA types

subspecialty services Figs. 1, 2, 3 and 4. show how organization and practice can prepare for an airway emergency.

Timing and Mode of Delivery

Understandably, the identification of fetal airway obstruction has significant implications for the plans surrounding the delivery. As with many other complex congenital anomalies, cases with suspected fetal airway obstruction should be referred for further evaluation to a tertiary center. Ideally such a referral center should have dedicated, multidisciplinary teams with advanced neonatal, otorhinolaryngology and pediatric surgery services with experience in fetal/neonatal airway issues. The course based on the diagnoses may comprise minimal noninvasive support to requiring EXIT delivery [5]. (Discussed in Chapters “Prenatal Assessment and Perinatal Management of Suspected Airway Compromise in the Fetus and Neonate” and “Operative Surgical Management of Fetuses with CHAOS, (Congenital High Airway Obstruction Syndrome): Management at Delivery”). The timing and choice of delivery will also be influenced by fetal and maternal health, particularly in cases of fetal hydrops and/or maternal “mirror syndrome” [6]. The most important thing when there is time to prepare is having experienced pediatric ENT present with full service tracheostomy tray and set up. Everyone should be prepared Figs. 5, 6, 7, 8 and 9.

Postnatal Diagnoses

In situations where the diagnoses of airway obstruction are not available or suggested prenatally, the clinician can get valuable information from the delivery room experience.

Respiratory distress, especially when unresponsive to routine resuscitative measures, is always an obvious presenting complaint of significant airway obstruction. Externally visible masses and dysmorphic features suggestive of micrognathia and/or retrognathia [7] can be important clues.

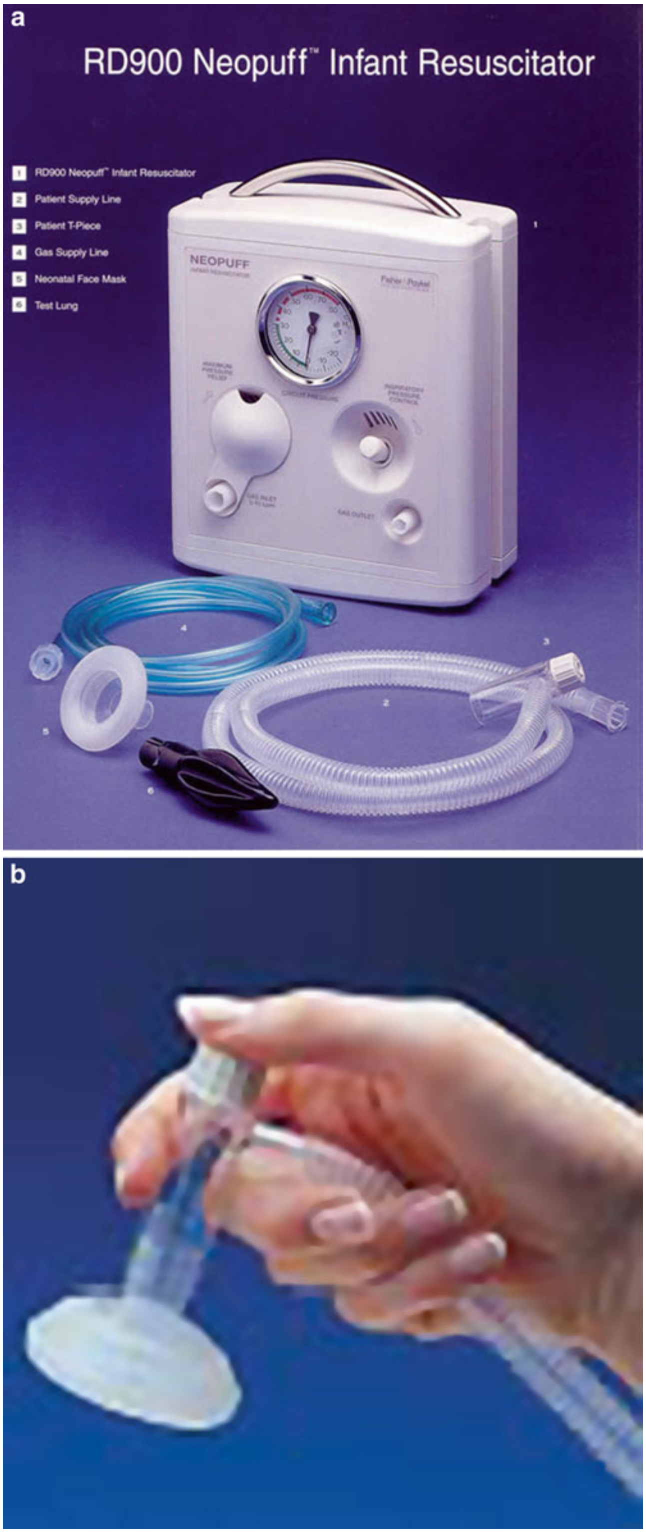

Fig. 4 (**a**) The Fisher Paykel NEOPUFF RD 900 Neopuff™ Infant Resuscitator. (**b**) Use of the mouthpiece with the Neopuff™ Infant Resuscitator

Fig. 5 Vocal Cord atresia causing airway obstruction during intubation

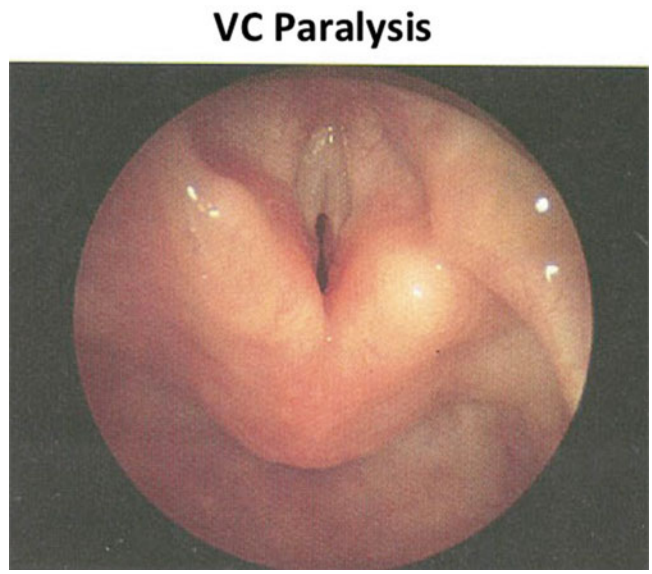

Fig. 6 Vocal Cord paralysis causing airway obstruction at delivery

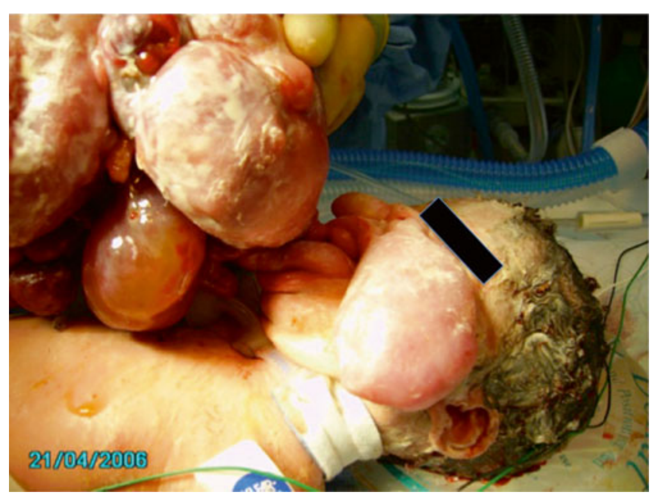

Fig. 7 Epulis/Epignathus causing acute oral obstruction and an airway emergency at birth Tracheostomy may be the only treatment for these types of obstructions

Other such symptoms may include excessive secretions, stridor, and inability to pass suction catheters through one or both nostrils Figs. 10, 11, 12, 13 and 14.

Birth Trauma

Finally, the possibility of birth trauma causing airway obstruction or impairment should be considered. This is especially true for macrosomic neonates with history of prolonged shoulder dystocia. While, such delivery circumstances may result in perinatal asphyxia, the clinician should still be cognizant of the possibility of airway trauma. Cases of tracheal or laryngeal tears are rare but have been reported in the literature [8, 9].

Fig. 8 Giant lymphangiomas causing acute oral obstruction and an airway emergency at birth Tracheostomy may be the only treatment for these types of obstructions

Summary of Delivery Room Management

Benefits exist in standardizing the care patients receive. We have discussed how things should be done in the delivery room regarding thermoregulation, oxygen titration, and respiratory support. However, the infrastructure to perform these interventions including who should perform which tasks requires some more detail. Understanding that we are trying to provide the best medical care, while training residents and fellows. We recommend the following guidelines to establish roles and responsibilities:

1. Establish a team leader—this person is usually a fellow for attending.
2. Airway—experienced personnel, usually a senior front line clinician, fellow for attending.
3. Umbilical Lines—should have an experienced person assisting residents to balance efficiency with training.
4. Nursing—at least one for baby (thermoregulation) and one recording. If possible, an additional medication nurse is optimal.
5. Respiratory Therapy—Need a dedicated person to manage CPAP nasal interface and oxygen titration. Surfactant administration if applicable.

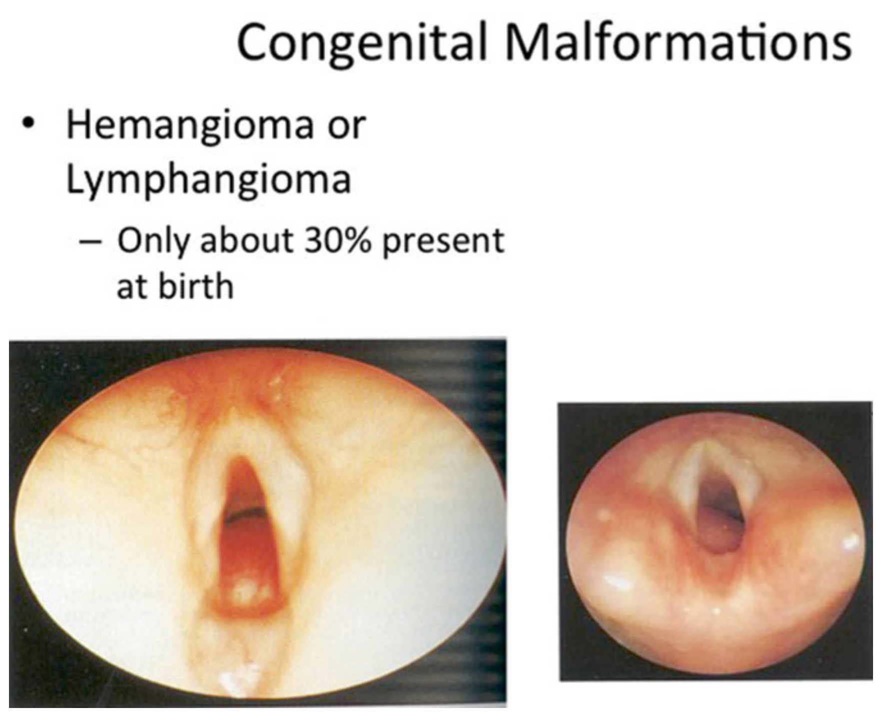

Fig. 9 Laryngeal Hemangioma or Lymphangioma can easily obstruct the entrance to the glottis and only be found upon intubation in a neonate with respiratory distress

Fig. 10 Standard type neonatal delivery room critical airway cart

Fig. 11 Emergency set up of delivery room resuscitation

6. Limit traffic—personnel without roles should leave the room, with rare exception. Attempt to keep doors closed to maintain room temperature.
7. Be prepared to handle unexpected situations arising out of unanticipated airway emergencies. Simple cues on physical exam and history maybe very important to direct management.
8. In cases of unexpected airway emergencies, understand your resources and involve specialists in a time-sensitive manner. Other teamwork guidelines apply with more focused communication and heightened sense of urgency.

Fig. 12 Emergency tracheostomy set up

Fig. 13 Essential basic delivery room airway equipment: LED laryngoscope handles and blades, LMAs, ETTs, masks, ETTs, and stylettes

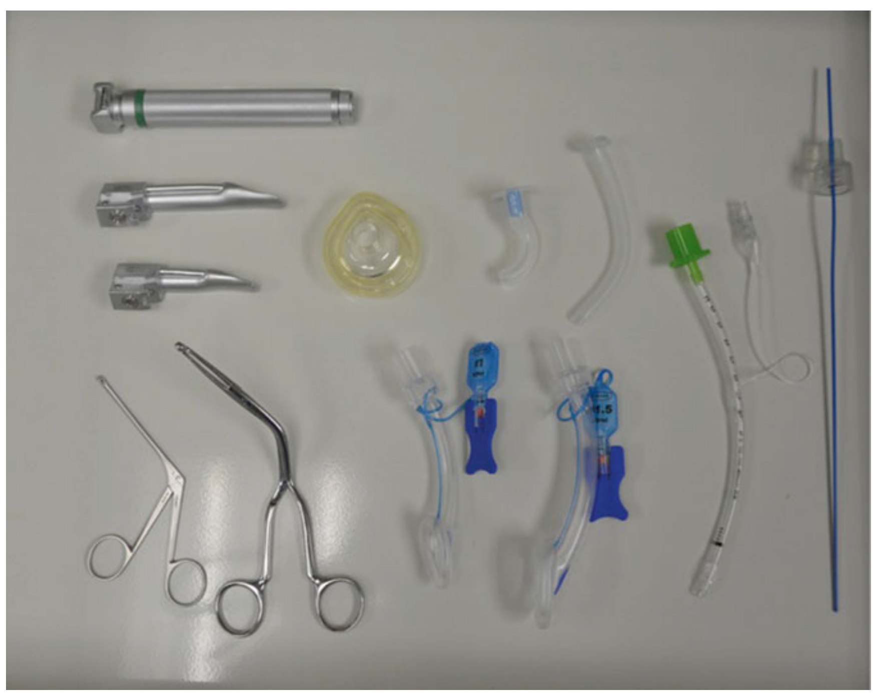

Fig. 14 Videolaryngoscopy: Glidescope and Storz CMAC now available for neonatal patients with size 0 and 1 blades

Section 2: Resuscitation in the Emergency Department

Nathan W. Mick and Joshua Nagler

Background

Neonatal airway management in the Emergency Department (ED) is an infrequent but critically important skill for emergency medicine providers. The psychomotor skills required to perform laryngoscopy and intubation in a neonate are similar to those utilized in the care of an older child or adult. However, there are key anatomic and physiologic differences between these disparately aged patient populations, which are most pronounced in neonates who are at the youngest end of the pediatric age spectrum. These differences impact the indications for airway management and necessitate modifications in approach.

Emergency medicine providers are further challenged by a relative inexperience in caring for critically ill neonates. Those with fellowship training in pediatric emergency medicine may have some additional experience from their neonatal and pediatric intensive care rotations as well as scheduled training in the operating room setting. However, the vast majority of neonatal intubations in EDs occur outside of a tertiary care children's hospital by providers with limited and often remote pediatric training. Nonetheless, neonatal and pediatric "readiness" is an essential component of general ED operations. Fortunately, most emergency medicine providers will have comfort in recognizing critical illness and responding quickly; however, there are a myriad of cognitive barriers (e.g., appropriate equipment sizes, drug doses) that make emergency airway management in neonates and children a source of significant anxiety.

Utilizing a systematic approach to airway management in young infants is paramount to success. This includes: (1) recognizing and addressing the predictable anatomic and physiologic differences in neonatal airway management, and (2) consistently applying an approach to airway management that identifies and addresses potential difficulties. In this chapter, we will review the most common presentations of neonatal patients requiring airway management in the ED, as well as provide a methodical approach to addressing both anticipated and unanticipated challenges that may occur.

Epidemiology and Experience

Opportunities to perform direct laryngoscopy and intubation are much less common in the pediatric than the adult population. It is estimated that airway management is required in 1–3 patients per 1,000 pediatric visits in the average ED compared with 6–10 intubations per 1,000 adult visits [10–12]. This number is further diluted when looking specifically at the care of young infants. The distribution of ages of patients requiring endotracheal intubation at a single tertiary care center for a 1-year period suggests that only a fraction of the pediatric population requiring airway management are neonates or young infants (Fig. 15). Given that the average ED physician will be unlikely to encounter opportunities for a significant number of pediatric airway procedures during typical clinical practice, skill acquisition, and retention can be difficult. Pediatric intubation success rates vary quite dramatically with experience. Studies performed in the operating room with anesthesia providers suggest that the success rate for endotracheal intubation after ten airways is less than 50 % while greater than 50 intubation attempts are required before success reaches 90 % [13, 14]. Therefore for emergency medicine providers with lim-

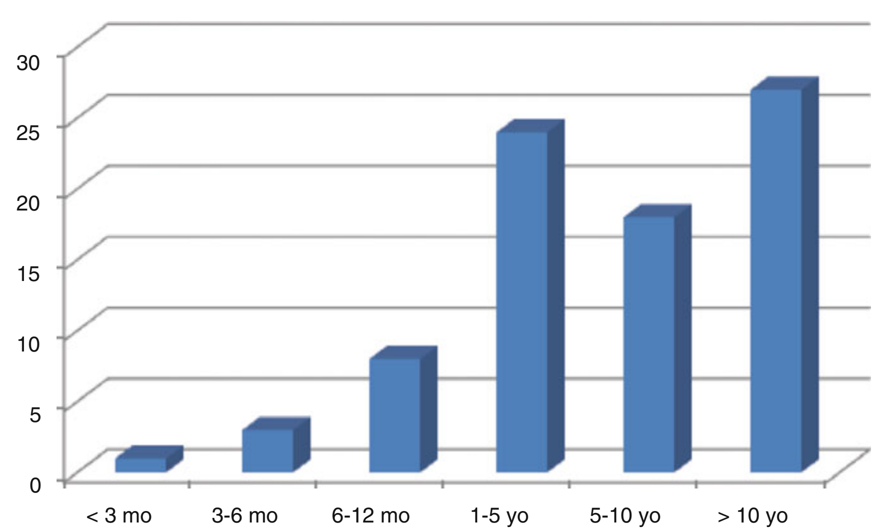

Fig. 15 Frequency of endotracheal intubation stratified by age

ited in situ clinical opportunities, the required number of intubations to attain “mastery” may therefore necessitate dedicated time in the operating room or augmentation of skills in a simulated environment [15].

Pathophysiology

There are many unique anatomic and physiologic features that impact emergent neonatal airway management. These differences are predictable, and therefore can be anticipated and addressed to optimize early success and mitigate adverse events.

Anatomic differences in neonates compared to larger children or adults include relatively large occiputs compared with body size, a superior and anterior larynx, a large tongue relative to the oral cavity, a weaker hyoepiglottic ligament, and a large floppy epiglottis. The impact of each of these unique features on airway management, as well as the strategies to accommodate them is reviewed in Table 5.

Physiologically, the most striking difference between neonates and their older pediatric and adult counterparts is the tendency toward rapid desaturation. This occurs as a result of increased oxygen consumption secondary to higher metabolic rates combined with decreased oxygen reservoirs reflecting relatively smaller functional residual capacities [16]. Also notable in neonates is increased vagal tone. This translates into a higher likelihood of bradycardia secondary to hypoxia, pharyngeal manipulation during laryngoscopy, or select medications (i.e., succinylcholine).

Table 5 Addressing anatomic differences in children

Anatomic difference	Effect	Approach to management
Large occiput	• Head flexion causes airway obstruction and limits glottic view	• Shoulder or neck roll to open airway and help align airway axes
Superior/anterior larynx	• May limit glottic view • Makes endotracheal tube delivery and passage difficult	• Look up during laryngoscopy • Apply external laryngeal pressure • Create acute angle to styletted endotracheal tube
Large tongue	• Falls onto posterior pharyngeal wall when supine obstructing airway • May impede laryngoscopy	• Airway maneuvers or oral or nasal airway to open upper airway • Sweep the tongue when obstructing glottic view
Weak hyoepiglottic ligament	• Limits elevation of epiglottis through vallecular pressure	• Use straight laryngoscope blades • Place the blade tip beneath the epiglottis and lift directly
Large epiglottis	• May fold on itself with placement of extragottic devices (EGD) • Obscures view during laryngoscopy	• Rotational technique for EGD insertion • Direct elevation of epiglottis with straight blade

Clinical Presentation

Indications for neonatal airway management in the ED are vastly different than those in the delivery room, and have only limited overlap with the Neonatal Intensive Care Unit (NICU) setting. Neonates returning after hospital discharge no longer have issues related to difficult transitions to extrauterine life, and are rarely in need of suctioning of meconium or delivery of surfactant. Instead, most indications for airway management in the ED are related to acute illness or injury, though the cohort of neonates with underlying conditions (i.e., chronic lung disease) may be at increased risk for decompensation from superimposed acute insults. Respiratory embarrassment and apnea are most common. Depressed mental status from sepsis, head injury, seizure, or shock with resultant failure to maintain or protect the airway are also relatively frequent indications to secure a child’s airway (Fig. 16). Data suggest that the number of intubations performed on trauma and non-trauma patients on children in the ED is approximately equal, though this distribution may differ when looking exclusively at neonates or young infants [11, 17].

General Algorithm

Consistently utilizing a systematic approach to airway management in patients of all ages is a sound strategy to reduce error, improve provider comfort, and minimize the “cognitive burden” inherent in pediatric procedures. Cognitive burden here refers to the mental load that is required to identify the correct drug dosing and equipment sizes across the age spectrum. There are several commercially available resuscitation aids (e.g., The Broselow–Luten System) that seek to minimize the challenge of addressing size or weight-based variables that occur in pediatric resuscitation (Fig. 17). These guides provide a means to identify the correct medication doses and equipment sizes for a pediatric patient based on weight or length with minimal or no reliance on mathematic calculations.

All patients who undergo intubation in the ED should have a pre-procedure airway assessment. Rapid sequence intubation (RSI) is the procedure of choice for emergency intubation in patients in whom difficulty is not anticipated. The LEMON© mnemonic can be used as a quick, reliable method to screen for the difficulty prior to laryngoscopy (Table 6) [18]. The LEMON© mnemonic can be summarized as follows:

L—Look externally: This is the gestalt "feel" of the patient and the airway and involves assessing for evidence of anatomic disruption as well as specific findings such as micrognathia (Fig. 18).

E—Evaluate 3-3-2: This step involves assessment of mouth opening, the length of the mandible, and the position of the glottis in relation to the base of the tongue (Fig. 19).

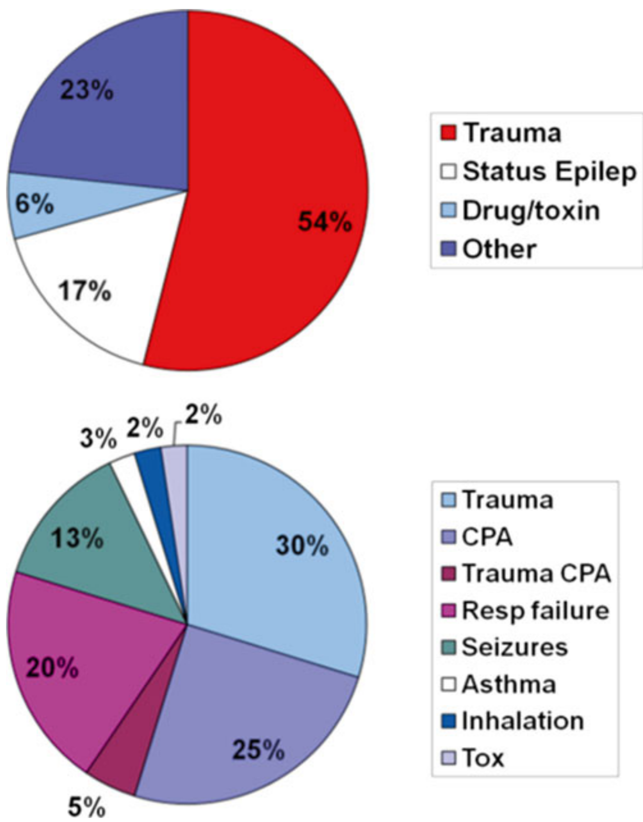

Fig. 16 Indications for intubation of pediatric patients in the Emergency Department. *Panel A*: Data from the National Emergency Airway Registry. *Panel B*: Data from Children's Hospital of Philadelphia

M—Mallampati score: This involves assessing how much of the posterior oropharynx is visible with the mouth open and the tongue protruded (Fig. 20). A modified version in children involves the use of a tongue depressor rather than reliance on voluntary protrusion of the tongue.

O—Obstruction or obesity: Evidence of upper airway obstruction, either by foreign body or swelling (i.e., croup or epiglottis may make laryngoscopy difficult. Obesity ought not be an issue in neonates but has been associated with airway management difficulty.

N—Neck mobility: Conditions that affect cervical spine mobility are very rare in neonates (either congenital or acquired). In the trauma setting, cervical spine immobilization with a cervical collar may impact laryngoscopic success.

Aspects of difficulty identified during application of the LEMON© mnemonic can be helpful in prompting emergency providers to alter their approach or recruit additional equipment or personnel prior to proceeding. Figure 18 shows an infant with Pierre Robin who would be identified as a potentially difficult airway based on the "Look" and "Evaluate" components of this screening strategy.

Once an airway assessment has been performed and intubation is felt to be indicated, RSI is the recommended approach. Prior to intubation, there are several preparatory considerations that will increase the likelihood of a smooth, successful procedure. As stated earlier, neonates have a high metabolic rate and are prone to rapid desaturation with apnea. Preoxygenation with a non-rebreather mask or BVM is critical if time allows. Neonates have a large occiput with respect to their bodies so proper positioning is important to allow for alignment of the oral, pharyngeal, and laryngeal axes. For these patients, a towel roll placed under the shoulders will elevate the body in relation to the head and put the patient in the proper position for laryngoscopy. The BURP (backward, upward, rightward pressure) maneuver can be helpful for glottic visualization, particularly in patients in whom cervical spine immobilization is in place.

EQUIPMENT		
E.T. Tube (mm)	3.5 uncff	3.5 uncff
Lip-Tip distance	10.5	10.5
Suction	8F	8F
Laryngoscope blade	1 straight	1 straight
Stylet	6F	6F
Oral airway	50 MM	50 MM
Nasopharyngeal Airway	14F	14F
BVM	INFANT	INFANT
VENTILATION**		
Tidal volume	60-100 mL	75-125 mL
Frequency (bpm)	20-25	20-25

Fig. 17 An example of the Broselow–Luten system for length-based estimation of equipment size and drug dosing

Table 6 Key features in applying the LEMON assessment in children

Look	• *Gestalt* is most important predictor • Dysmorphic features associated with abnormal airways
Evaluate (3:3:2)	• Not tested in children, difficult with "pudgy" necks • If attempted, use child's fingers
Mallampati	• Cooperation may be an issue • Mixed data in children
Obstruction	• Common indication for airway management in children • Focused disease history is key • Obesity is growing concern in children
Neck	• Limited positioning secondary to trauma similar to adults • Intrinsic congenital or acquired anomalies are rare

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Fig. 18 Micrognathia in the Pierre Robin sequence

Ideal equipment for intubation in neonates consists of a straight (i.e., Miller) laryngoscope blade and a styletted, cuffed endotracheal tube. Young children have large epiglottises that are most amenable to manipulation with a straight blade. Stylets can be safely used in pediatric patients and have benefits in both direct and video laryngoscopy to direct the tip of the tube through the cords. Although uncuffed endotracheal tubes have been traditionally used in airway management in the ED, there are many situations where a cuffed tube may be beneficial. The admonition to "never use a cuffed tube" in pediatric patients is a historical argument arising from a time when large cuffs would necessitate use of significantly smaller diameter tubes, and cuff pressures could not be reliably monitored. High cuff pressures placed the patient at risk for tracheal ischemia and resulting subglottic

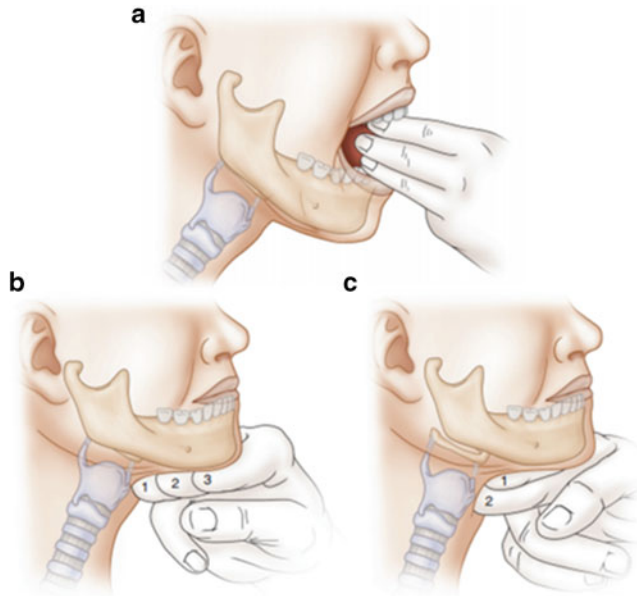

Fig. 19 (**a–c**) Show key features of the 3-3-2 rule to assess for likely anatomic difficulty aligning the oral, pharyngeal, and laryngeal axes for intubation. Used with permission from Walls RM and Murphy MF: Manual of Emergency Airway Management, 4th Edition, Philadelphia, Walters Kluwer, 2012

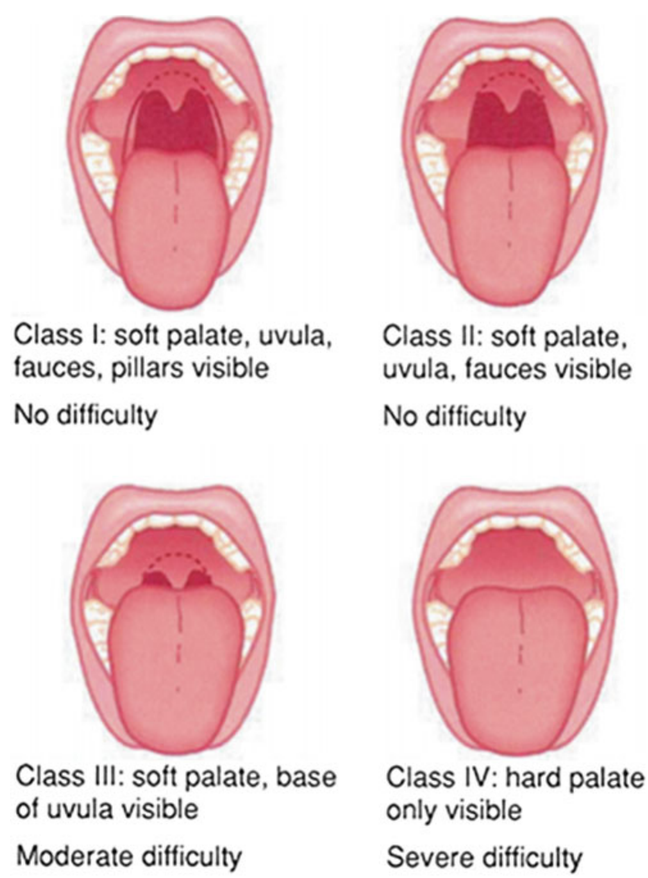

Fig. 20 The Mallampati scale used to predict difficult laryngoscopy based on the extent of the posterior oropharynx visible with the mouth open and tongue protruding. Used with permission from Walls RM and Murphy MF: Manual of Emergency Airway Management, 4th Edition, Philadelphia, Walters Kluwer, 2012

stenosis. Recently, there has been increasing use of cuffed tubes in the ED, ICU, and operating room owing to modern tubes that are manufactured with the ability to more carefully monitor cuff pressures. In addition, increasing cuff inflation may be useful to prevent air leak in cases where high airway pressures are necessary or changing lung compliance is likely (i.e., ARDS, reactive airway disease).

Correct endotracheal tube placement should be confirmed using either quantitative or qualitative end-tidal carbon dioxide monitoring. Disposable qualitative end-tidal carbon dioxide devices are most frequently used. They typically come in an "adult" and "pediatric" size. The pediatric-sized devices are appropriate for use in neonates (as low as 1 kg body weight) and have the advantage of a smaller internal volume and lower resistance to flow. There is concern that applying an adult qualitative device to an intubated neonate will result in a false "negative" reading even when the endotracheal tube is correctly placed due to the low tidal volumes circulating through the device. Similar concerns have been raised about using the pediatric size for extremely low birth weight infants. However, for patients large enough to have been discharged from the NICU, these colorimetric capographs have been deemed to be reliable.

Post-intubation management of the neonate intubated in the ED revolves around careful attention to patient movement to prevent tube dislodgement and appropriate sedation. Multiple different methods of securing the endotracheal tube have been shown to be effective. These include taping to the mouth/upper lip, tape around the neck, and commercially available tube holders.

Young age has been shown to be an independent risk factor for ETT dislodgement [19]. Appropriate sedation can limit this risk. Post-intubation sedation is best achieved in the ED with intermittent boluses of a sedative such as midazolam or lorazepam. Continuous infusions of propofol, a staple in adult airway management post-intubation, is to be avoided due to the risk of propofol infusion syndrome.

Rapid Sequence Intubation

The immediacy of need for neonatal resuscitation in the delivery room means that airway management often occurs prior to vascular access. As such, both bag-mask ventilation and endotracheal intubation in this setting almost always occur without premedication. In the NICU, however, the utilization of premedication for intubation is becoming more common, particularly in non-emergent cases; a practice supported by AAP issued guidelines [20–22].

In the Emergency Department, the vast majority of patients, regardless of age, are intubated using RSI. Based on the systematic approach described above, any neonate who is deemed to require intubation and is not immediately identified as a crash airway should be screened for difficulty. If no risk factors for difficulty are identified, these patients should undergo RSI.

By definition, RSI involves the delivery of premedications, sedatives, and neuromuscular blocking drugs for the purpose of decreasing awareness, pain, and movement (including protective airway reflexes) to facilitate emergent endotracheal intubation and to minimize the risk of aspiration. Given the certainty of apnea in this approach, preoxygenation is vital to reduce the likelihood of clinically significant hypoxemia. There is no single combination of medications that is optimal in all circumstances. Instead, selection will vary based on hospital protocols, clinical context, and provider familiarity and comfort. However, an overview of commonly used medications follows below.

Given the propensity for bradycardia from increased vagal tone in this young population, premedication with atropine is recommended. Although the data to support the ability of atropine to diminish the occurrence or severity of bradycardia is limited, its use is supported by anecdotal experience as well as biological plausibility. In addition, as a medication with very little cost or downside, the potential benefit outweighs the relatively low risk of harm. Atropine may also be helpful in drying secretions though this effect does not occur for 15–20 min after administration which will often be well after the patient has been intubated.

The safety profile and efficacy of various sedatives and analgesics in neonates continues to emerge. In addition, hospital protocols will guide which medications are available for use in EDs. However, there are certain mainstays within the pharmacopeia that should be familiar to emergency medicine practitioners. Opioids have the advantage of combining a potent analgesic effect with sedative properties. Although morphine can be used, fentanyl has a pharmacokinetic profile that is much better suited for RSI, with onset of action within 30 s and peaking in just a few minutes. Remifentanil is used in many NICUs, though it is not commonly used in EDs. Midazolam is commonly used in combination with fentanyl to provide additional sedative as well as amnestic qualities. When using this drug combination, careful attention for compromise in spontaneous respiratory effort and hypotension is warranted. Data regarding isolated midazolam use in preterm infants shows a high rate of peri-intubation decompensations, though this has not been similarly demonstrated in term infants and therefore is not an issue for ED management [23]. Etomidate is a favorite sedative for RSI in pediatrics given its predictable efficacy and stable hemodynamic profile. Ketamine has the advantage of analgesic and amnestic effects, hemodynamic support, and bronchodilatory effects. It has been demonstrated to be effective and safe for use in the neonatal age group, and concerns related to neurodegenerative effects in neonatal animal models have not been shown to translate into use in human infants or older children [24].

Propofol induction is a favorite of anesthesiologists, and is becoming more commonly used in EDs. It has been shown to be both safe and effective for RSI with extremely rapid and predictable effects. There are, however, three relevant precautions regarding the use of propofol: (1) prolonged infusions should be avoided given the risk of propofol infusion syndrome, (2) optimal dosing for RSI has not been well established in young infants, and (3) hypotension is a relatively common effect and should be anticipated.

Use of neuromuscular blocking drugs is commonplace for older children and adults; however, many providers are more reluctant to do the same when attempting neonatal intubation in the ED. One reason for this is that it is relatively easy to overcome the limited strength of neonates and perform laryngoscopy and endotracheal intubation without pharmacologic assistance. A second reason is that providers may have reluctance to deliberately compromise spontaneous respiratory effort based on fear that they may have difficulty successfully intubating the child. Nonetheless, studies have demonstrated that intubation success rates of newborns in the NICU as well as pediatric patients in the ER favors the use of neuromuscular blocking drugs [17, 25]. Succinylcholine has the advantage of rapid onset and offset, and predictable pharmacokinetics whether given intravenously or intramuscularly. It should not be used in patients with hyperkalemia, or patients known or suspected to have any type of neuromuscular disorder. Although an FDA Black Box warning exists for succinylcholine use in children, it includes the qualifier that is "should be reserved for emergency intubation or instances where immediate securing of the airway is necessary." This justifies its common use in the ED setting. Rocuronium is the other neuromuscular blocking drug frequently used in neonatal and pediatric intubation in the ED. Initial dosing at 0.6 mg/kg resulted in a longer time to intubating conditions. However, currently supported dosing at 1.2 mg/kg has been shown to reach intubating conditions in an equivalent time frame as succinylcholine. Rocuronium has the advantage of safe use in patients in whom hyperkalemia or neuromuscular disease exists, or simply is not known. However at the higher dosing schedule, it also has a much longer duration of action than succinylcholine. This needs to be considered in a patient in whom difficulty with intubation is possible, or in patients in whom a neurological examination or a return to spontaneous respiration is needed quickly.

Videolaryngoscopy

If a patient has clinical features that suggest airway management may be difficult (e.g., LEMON screen is positive), then alternative approaches should be considered. Videolaryngoscopy has emerged as a favored approach in these clinical circumstances. Given that neonates are likely to have the most anterior and superior larynx, the wider viewing angle offered by these devices may afford improved visualization, even in those not anticipated to be "difficult." Therefore, many emergency medicine providers will use videolaryngoscopy as a primary approach even for routine neonatal intubations as well.

Numerous studies demonstrate that videolaryngoscopy offers improved views over conventional direct laryngoscopy in children. The benefit of "seeing around the corner" of the airway rather than needing to line up the oral, pharyngeal, and laryngeal axes to provide a direct line of site has been clearly described [26]. In addition, data suggest that videolaryngoscopy has a relatively shorter learning curve than traditional direct laryngoscopy for less experienced laryngoscopists, which is likely to be true for most emergency medicine providers caring for neonates. Finally, although more of a secondary benefit, the shared view during videolaryngoscopy also provides an educational opportunity for more experienced providers to teach or guide this critical procedure.

Although a number of video-assisted devices exist for the management of pediatric patients, only a few currently include a complete range of sizes that would allow for their use in a child as small as a neonate. Glidescope has blades sizes for use down to preterm infants, Storz C-MAC has a Miller 0 blade, and Airtraq has a size 0 device that accommodates endotracheal tubes down to size 2.5 mm. Different options exist for disposability versus reusable blades, proceduralist viewfinder versus video screen display, and recording abilities. Importantly, differences in construction and blade angle require somewhat different technique for each, and therefore separate training and experience is required for any given device to be used.

Clinical data support the successful use of videolaryngoscopy in the ED; however, pediatric-specific data in this context is limited. The majority of reported experience using videolaryngoscopy in children comes from anesthesia literature, with several case series demonstrating successful use specifically in neonatal airway management, both routine and difficult [27–29] Therefore, given emergency medicine providers comfort and familiarity with videolaryngoscopy with demonstrated benefit in the ED setting, coupled with data demonstrating feasibility and safety in neonates, this approach is becoming increasingly common in the emergency management of critical neonatal airways.

Extraglottic Devices

Another available approach to the management of critical neonatal airways in the ED is the use of extraglottic devices (EGD). Case series and observational trials as well as randomized controlled trials support laryngeal mask airways as a feasible and safe modality for neonatal resuscitation [30]. EGD may be helpful as the primary approach for patients anticipated to have difficult airway management or as a rescue device in circumstances of unexpected inability to intubate.

Bag-mask ventilation, as described above, is the most fundamental and immediately available approach to supporting a child's respiratory effort emergently. However, the ability to maintain an adequate mask seal and patency of the airway requires ongoing effort. This may consume personnel resources and requires persistent, deliberate attention to the task, which can easily wane in the chaotic environment of the ED. In addition, mask ventilation, even when using appropriately limited pressures can easily lead to gastric insufflation as positive pressure breaths travel from the hypopharynx down the esophagus as well as into the trachea, unless gentle cricoid pressure is maintained. An appropriately placed EGD allows for similar ventilation pressures without the need for a continuous mask seal. The risk of gastric inflation is lower, and some devices now have a channel through which to pass a nasogastric tube to allow gastric decompression. Nonetheless, an EGD is not considered a "secure" airway, and the patient remains at risk of aspiration were secretions or gastric contents to pass the glottis.

The first clinical circumstance where an EGD might be used in the ED is in a child anticipated to have an anatomically difficult airway. In this circumstance, proceeding to RSI and relinquishing spontaneous ventilation may be risky. Primary placement of an EGD provides a relatively secure means to support oxygenation and ventilation. Awake patients will not tolerate an EGD, therefore this strategy is only effective in patients who have a depressed level of consciousness secondary to their underlying illness or injury, or secondary to pharmacologic sedation.

A more commonly recognized use of EGDs in the ED is as a rescue device following failed airway interventions. That is, for patients requiring respiratory support but in whom laryngoscopy and endotracheal intubation is not successful, an EGD can be placed as an alternative management strategy.

First pass success rates for placement of EGDs is very high, even by less experienced providers [30]. For young children, placement using a rotational technique may be advantageous to insure that epiglottis does not fold on itself and block the glottic opening following placement [31]. Once placed, the EGD may serve as the primary means of oxygenation and ventilation until a patient no longer requires respiratory support, or may serve as a bridge until endotracheal intubation can be performed by an experienced provider. In addition to serving as a temporizing approach, select EGDs can be used as conduits for endotracheal intubation, most safely accomplished with a flexible bronchoscope. Although many EGDs have aperture bars that preclude the passage of a scope or an endotracheal tube, newer generation devices use alternative designs with no obstructing features allowing easy passage of a tube through the EGD into the glottic opening.

Surgical Devices

The incidence of truly difficult pediatric intubations is estimated to be much less than 1 %. Airway difficulty may be encountered in the rare case of a previously undiagnosed congenital midface abnormality or in acquired conditions such as upper airway infection (i.e., tracheitis) or trauma. In the rare case of a neonate who cannot be intubated orotracheally and in whom ventilation via BVM or EGD is not possible (can't intubate, can't ventilate CICV), a surgical approach to airway management is indicated. In the CICV scenario in a neonate, surgical cricothyrotomy is exceedingly difficult due to the small size of the cricothyroid membrane and its position high in the neck. In small infants, needle cricothyrotomy (or more aptly named needle tracheostomy) is indicated. Needle tracheostomy has its basis in early animal studies using dogs, during which oxygenation was accomplished through a percutaneous catheter in the neck [32]. Using this technique, oxygenation was maintained for up to 1 h which conceivably could allow for additional orotracheal attempts as well as summoning additional resources to the bedside to aid in definitive airway management.

Diagnosis

The clinical conditions most commonly associated with the need for ED endotracheal intubation in the neonate are respiratory emergencies such as bronchiolitis, sepsis, and trauma.

Bronchiolitis

Neonates with bronchiolitis frequently require airway management due to centrally occurring apnea as well as respiratory fatigue from secretions and increased work of breathing. Nasal continuous positive airway pressure has been shown to improve respiratory outcomes in neonates with bronchiolitis and may be considered prior to intubation in select infants [33, 34]. If intubation is indicated and no difficult airway predictors are present, RSI is the procedure of choice. Preoxygenation will potentially be very difficult due to lower respiratory tract congestion. Atropine (0.02 mg/kg, minimum 0.1 mg) should be a strong consideration due to age. Induction with either etomidate (0.3 mg/kg) or ketamine (1–2 mg/kg) followed by paralysis with either succinylcholine (2 mg/kg) or rocuronium (1.2 mg/kg) would be reasonable choices.

Sepsis

Neonatal sepsis can present with fever or hypothermia or more protean manifestation such as increased sleepiness, poor perfusion, or poor feeding. Intubation may be indicated in situations in which the child's oxygenation is poor due to a pulmonary source of infection (i.e., pneumonia, viral causes) or the infant's work of breathing is leading to respiratory failure and fatigue. In the poorly perfused infant with sepsis, pretreatment with aggressive IVF (60 cc/kg over the first hour of resuscitation in 20 cc/kg aliquots) and consideration of vasopressor support can be critical to ensure that circulatory collapse does not occur peri-intubation. Atropine should again be strongly considered. Etomidate is somewhat controversial in the setting of sepsis due to concerns about cortisol insufficiency in critical illness [35, 36]. It is known that etomidate reversibly suppresses adrenal hormone production but it has not been shown to conclusively affect mortality. If etomidate is felt to be contraindicated, ketamine is a reasonable alternative for induction with either succinylcholine or rocuronium given for paralysis.

Trauma

In the setting of trauma, airway management may be indicated due to failure of oxygenation or ventilation or depressed mental status with the inability to protect the airway. Many of these neonates may be in a cervical collar which will make it difficult to optimally position these children. This difficulty can be overcome by removing the front of the cervical collar and holding manual in-line stabilization during direct laryngoscopy and employing videolaryngoscopy (if available) which allows for better visualization of the glottis. In the hemodynamically unstable trauma patient, induction with etomidate, which has a stable cardiovascular profile, or ketamine is preferable. There is a growing body of literature suggesting ketamine is safe, even in cases of neurotrauma, particularly when the patient is hemodynamically compromised [37, 38].

Multidisciplinary Considerations

Advanced airway management in the neonatal population is a rare procedure for many practicing emergency providers. RSI should only be performed by practitioners skilled in the practice. In cases where no practitioner who has trained in intubation is present, ventilation with BVM or an EGD can be lifesaving. When feasible, it may be helpful to consider consultation with a neonatal intensivist, ENT surgeon, or pediatric anesthesiologist and approach airway management in a multidisciplinary fashion.

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